(NASA-TM-109786) THE APOLLO PROGRAM AND THE BALANCE BETWEEN PUBLIC AND PRIVATE ENTERPRISE (NASA) 32 p

N94-71991

Unclas

Z9/12 0012433

PAPER IS RECIPIENT OF THE LILLY AWARD FOR OUTSTANDING RESEARCH TO BE PRESENTED AT THE 1992 NATIONAL CONFERENCE OF THE AMERICAN SOCIETY FOR PUBLIC ADMINISTRATION

NASA-TM-109786

# THE APOLLO PROGRAM AND THE BALANCE BETWEEN PUBLIC AND PRIVATE ENTERPRISE[1]

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7N-12-TM
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P-32

December 1991

The conventional separation in our universities of business schools and schools of public administration reflects a widely held belief that managing a private sector enterprise and managing a government agency involve sufficiently discrete and indigenous challenges that an expert in one sector may be a complete amateur in the other. Bureaucrats and businesspeople become strangers to each other when talk turns to exploiting markets, improving products, and return on investment.

Our political culture has reinforced this separation. On the one hand it has maintained a protective constitutional barrier around private individual and corporate realms with only well-litigated incursions. On the other hand, progressives of both major parties have launched periodic campaigns to ensure the integrity of the civil service, of which the Pendleton Act of 1883 was a major victory. From recent "Ethics Reform" regulations designed to decelerate the "revolving door" between government and industry, to "competition in contracting" legislation designed to eliminate favoritism in procurement, Federal policy and practice has sought to protect the so-called public interest from corporate incursions. The catch phrase, "conflict of interest," aptly alludes to this peculiarity of American political culture.

The tacitly held assumption that government controls over the private sector should be minimal has been seriously challenged during our history only in periods of national emergency. Through two world wars government mobilized industry on a national scale to provide materiel and armaments, while government interference with the

[1] I am indebted to Roger D. Launius, Norman R. Augustine, Noel W. Hinners, Daniel J. Fink, and Caleb B. Hurtt, who read earlier versions of this essay and provided valuable comments.

marketplace was tolerated only because everyone understood it to be temporary. Government manipulations at the periphery of private sector production sufficed--that is, the federal government was able to redirect the production priorities of U.S. industry by regulating resources, prices, and wages. Wartime industrial mobilization succeeded with negligible government involvement in the internal management of American industry itself.

Less widely appreciated is the way the federal government carried out the Apollo program, the largest industrial mobilization in peacetime since the building of the Panama Canal. The successful landing of two Americans on the Moon in July 1969, not to mention their safe return, were achieved without reinstituting the devices of two previous wartime mobilizations. The $25 billion allocated by the Congress during the 1960s[2] were necessary, but not sufficient, to ensure the success of that Cold War campaign for the respect and admiration of the 'Free World.' The ramifications of that campaign, of how it was fought and won, would reach well beyond the excitement of seeing, televised, the first imprint of human footsteps on the Moon.

Mobilization for the Apollo program led to a disequilibrium in the respective roles played by the private and public sectors in the country's industrial and political economy. For a brief period the federal government, through the National Aeronautics and Space Administration (NASA), conducted a massive research and development enterprise of extreme audacity and complexity. Because of the novelty and sophistication of the technology the still young aerospace industry had contracted to produce for the Moon landing campaign, NASA contracts for the Apollo spacecraft and Saturn launch systems served as vehicles by which the government forced the development of the aerospace industry and a recasting of the strategies by which that industry managed the design and manufacture of its products.

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[2] NASA's aggregate budget authority, FY 1962 through FY 1967, in current dollars and less sums authorized for aeronautical activities, was $25,471.8 million.

When demobilization after the Apollo triumph occurred, NASA was not dismantled. No plans for the orderly reabsorption of its specialized workforce into civilian life were made because policy had defined, and the government had executed, the Apollo program as a peacetime, civilian undertaking. Justifying the continuation of government-funded and government-managed space enterprise became increasingly problematic: Did NASA still have a unique role, not to mention a unique reservoir of managerial and technological know-how, to offer the country? Much of the ongoing debate reflects a struggle to recover an equilibrium between the private and public sectors in the exploitation of space.[3]

## Mobilizing to Go to the Moon

The Cold War--most notably in the "Sputnik Crisis" and the Cuban Missile Crisis--stimulated not only the creation of NASA in 1958 but its tremendous expansion in the early 1960s to carry out the Apollo Program.[4] After President John F. Kennedy issued his challenge to the nation in May 1961 NASA undertook a mobilization comparable, in relative scale, to that undertaken by the U.S. to fight World War II. Between 1960 and 1965 the agency's annual budget increased an order of magnitude, from nearly $500 million to $5.2 billion. Nine out of every ten federal dollars were spent on goods and services procured from the private sector. Likewise, NASA's civil service personnel rolls increased by a factor of three, while the men and women employed by NASA contractors

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[3] Pure space exploration, or space science, remains a widely accepted role for NASA attributable to the fact that the agency thereby sustains a variety of scientific disciplines within the non-profit educational sector.

[4] Thanks to the GI Bill and its Korean War counterpart, the military services' reserve officers' training programs, cooperative work-education programs, and draft exemptions for those in engineering school or working for the government in engineering fields--NASA and its contractors were able to mobilize unprecedented numbers of engineers and scientists.

increased by a factor of 10. In 1965 91.7% of "NASA employees" were actually on the payrolls of private sector contractor and subcontractors.[5]

The Apollo program also led to significant government penetration into the management processes of the young aerospace industry. The resulting convergence of corporate and public sector research and development management practices served as the catalyst for the emergence of American industry's ability to develop, manufacture, and operate large, complex and sophisticated technical systems. In 1968 *Science* magazine, the publication of the American Association for the Advancement of Science, observed:

> In terms of numbers of dollars or of men, NASA has not been our largest national undertaking, but in terms of complexity, rate of growth, and technological sophistication it has been unique.... It may turn out that [the space program's] most valuable spin-off of all will be human rather than technological: better knowledge of how to plan, coordinate, and monitor the multitudinous and varied activities of the organizations required to accomplish great social undertakings.[6]

## Managing for Sophisticated and Reliable Technical Systems

The forces that have shaped the management strategies characteristic of American industries at any given time have varied both with the characteristics of the contemporary market place and with the nature of the goods being produced. For example, during the 1880s and 1890s firms producing relatively undifferentiated goods (e.g., whiskey, salt, coal,

[5] NASA's civil service workforce grew from 10,200 in 1960 to 34,300 in 1965. The number of its contractor employees expanded more dramatically from 36,500 in 1960 to 376,700 in 1975. Source: Jane Van Nimmen and Leonard C. Bruno with Robert L. Rosholt, *NASA Historical Data Book, Vol. I. NASA Resources, 1958-1968*. NASA SP-4012. (Washington, D.C.: U.S. Government Printing Office, 1988), Table 3-26, pp. 118; p. 171.

[6] Dael Wolfe, Executive Officer, American Association for the Advancement of Science, editorial for *Science* magazine (November 15, 1968).

tobacco, sugar, kerosene) attempted to combine financial as well as management structures to achieve more effective market control through control of production and pricing. Toward the end of the century such combinations were increasingly subject to state and federal anti-trust legislation. Successful prosecutions under the Sherman Anti-Trust Act of 1890 brought about the dissolution of such 'horizontally integrated' firms as the Standard Oil Company of New Jersey and the American Tobacco Company.

Meanwhile, firms that began to produce increasingly complex manufactured items sought to achieve economies of scale in an expanding market through mass production and volume retailing, (e.g., sewing machines, automobiles, typewriters). By integrating vertically--controlling as many steps in the production of an item as possible, from raw material through manufacture and even marketing--firms (e.g. Carnegie Steel) combined to create even larger companies better able to withstand the economic oscillations of the period between the end of the Civil War and 1896.

The new large enterprises of the turn of the century could no longer be administered informally, with control of markets management's principal preoccupation. Creative managers of some of these enterprises (in, for example, the tobacco, meat-packing, and agricultural power machinery industries) developed the centralized, functionally departmentalized organizational structure. After 1900, a new wave of expansion occurred in industries exploiting new technologies such as electrification and the gasoline engine. Product diversification became a common strategy for expansion in firms that could exploit systematic research and development--firms in the chemical, rubber, automobile, and electrical industries.

Product diversification, in turn, required a different organizational approach to management. The strategy of diversification was followed by decentralization in these firms' organizational structures. Decentralization, however, posed its own administrative problems. How was authority to be distributed among headquarters and field activities?

The most widely adopted solution was that developed, during the previous half-century, by all major military forces and by managers of the railroads: the multi-divisional line-and-staff organization, by which authority was delegated from headquarters to field commanders and local or regional plant managers (who could not otherwise be held accountable for the performance of their units), while managers of centrally located auxiliary or service functions set standards and procedures.[7]

In post-World War II America several new forces began to make themselves felt on American industry and, as a consequence, gave rise to new management strategies. Among them was the entrance of the public sector--primarily the federal government--into the marketplace as a significant buyer. Another was the emergence of a substantial market for, and a corresponding productive capacity for, goods and services having highly sophisticated technological components.

The importance of technological sophistication as a driving force in this new market cannot be overestimated. The largest public sector buyer, the military establishment, seeking out ever improved weapons systems, funded industrial research and development both indirectly as a buyer of newer and more advanced systems, and directly as the largest single investor in research and development.[8] How much the American economy has been affected by these two factors--the federal government as principal buyer, and that buyer's interest in new technologies--is reflected in the top five industries

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[7] Alfred D. Chandler, Jr., *Strategy and Structure: Chapters in the History of American Industrial Enterprise* (Cambridge: M.I.T. Press, 1962), Chapters 1, 2, *passim*.

[8] Ross M. Robertson, *History of the American Economy*, 2nd ed. (New York: Harcourt, Brace & World, Inc., 1964), p. 555. In 1946-47 the federal government paid 24 percent, and industry paid 72 percent, of the dollars (est. $2.1 billion) spent on industrial research and development during that period. By 1969 the federal government's share of the total (est. $28 billion) had increased to 40 percent and industry's share declined to 58 percent. Which sector (private or public) actually spent the rapidly increasing number of dollars devoted to research and development during 1946-1969 underwent a comparable change: industry spent 62 percent of the nation's R & D dollars on 1946-7 and 76 percent in 1969.

(measured by sales) in the United States in 1988. Heading the list are two American industries well-established before World War II: petroleum refining ($284.3 billion) and motor vehicles and parts ($273.1 billion). Third, fourth, and fifth are industries that were initially stimulated by the federal government's post-1940s appetite for technologically sophisticated systems and its ability to pay for them: electronics ($115.3 billion), aerospace ($112.8 billion) and computers and office equipment ($112.6 billion). The sales and capital represented by these figures grew on a foundation of successfully managed government research and development programs executed largely in the private sector.

To appreciate the complexity of the technical management and quality controls (not to mention coordination and accounting) that government and industrial managers faced in assuring the success of the Apollo program, consider the prime contracts awarded to industry to design, build, test, and certify the principal components of the Apollo/Saturn vehicles alone: Boeing Co., S-IC first stage of the Saturn V rocket; North American Aviation (after 1967, North American Rockwell Corp.), S-II second stage; Chrysler Corporation Space Division, S-I lower stage; Douglas Aircraft Corporation,[9] S-IV upper stage and upper stages of Saturn IB and Saturn V; Pratt & Whitney, RL-10 engine (in clusters of 6, powered the S-IV vehicle), Rocketdyne Div. of North American Aviation, J-2 engines that powered the S-II and S-IV upper stages; and International Business Machines (IBM), Saturn instrument unit.

Were this the extent of industrial contractor involvement in the program, that would have been enough of a challenge for both government and corporate managers. In addition, a partial listing of the subcontracts awarded to other firms that "played a major role in the development and production of the Saturn V launch vehicle" would have to include the 50 subcontractors to Boeing, 91 subcontractors to Douglas Aircraft, 54

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[9] In 1967 Douglas Aircraft Co. and the McDonnell Corp. merged, becoming the McDonnell Douglas Corporation. The former Douglas division in California became the McDonnell Douglas Astronautics Co., (MDAC).

subcontractors to IBM, 28 subcontractors to North American Space Division, and 51 subcontractors to North American Rocketdyne.[10] These well over 250 firms provided innumerable parts and components, ranging from hydraulic hoses to analog computers, all of which had to meet exacting specifications for integrated fit and performance. "I wish to emphasize," remarked a NASA procurement officer during the bidding for the Saturn rocket S-II stage contract, "that the important product that NASA will buy in this procurement is the efficient management of a stage system."[11] How did NASA acquire the competence to insist on "efficient management" from the aerospace industry in the design and production of sophisticated technical systems?

Instruments of Mobilization

The Eisenhower Administration's calculated policy of "open skies" and "peaceful uses of space" to enable satellite overflights of other nations (principally the Soviet Union) that might threaten the United States[12] virtually assured that when this country launched its own space program in 1958, it would be lodged in a civilian agency. Eisenhower's unease over an emerging military-industrial complex no doubt also contributed to his view that all non-defense related space activities should be assigned to a new civilian organization. Scientists--who believed that scientific exploration of space would fare better in a civilian program--agreed with Eisenhower. The National Advisory Committee for Aeronautics (NACA; est. 1915) seemed the best candidate:

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[10] Roger E. Bilstein, *Stages to Saturn: A Technological History of the Apollo/Saturn Launch Vehicles*, NASA SP-4206 (Washington, D.C.: National Aeronautics and Space Administration, 1980), *passim*, and Appendix E.

[11] NASA Marshall Space Flight Center, "Minutes of the Phase II Pre-Proposal Conference for Stage S-II Procurement on June 21, 1961," JSC files. Quoted in Bilstein, *Stages to Saturn*, p. 211.

[12] See R. Cargill Hall, "Prelude to the Space Age: Eisenhower, Open Skies, and Freedom of Space," *A Documentary History of the Space Age*. Forthcoming in the NASA History Series. On file in NASA History Division Reference Collection, NASA Headquarters, Washington, D.C.

> NACA is a going Federal research agency with a large scientific and engineering staff...and a large plant.... It can expand its research program and increase its emphasis on space matters with a minimum of delay and can provide a functioning institutional setting for this activity. NACA's aeronautical research has been progressively involving it in technical problems associated with space flight.... It has done research in rocket engines.... NACA has a long history of close and cordial cooperation with military departments...the tradition of comity and civil-military accommodation which has been built up over the years will be a great asset in minimizing friction between the civilian space agency and the Department of Defense.[13]

Created by the National Aeronautics and Space Act (PL 85-568), NASA opened for business in 1958 with a complement of nearly eight thousand employees transferred from the NACA. By the end of 1960 NASA personnel rolls had nearly doubled to over sixteen thousand. The principal increases occurred largely at NASA Headquarters (where personnel more than tripled), and with the addition of the Army's Ballistic Missile Agency (ABMA; renamed the George C. Marshall Space Flight Center) and the new Goddard Space Flight Center in Beltsville, Maryland. Most of Goddard's personnel had been transferred from the Naval Research Laboratory (NRL) and the Naval Ordnance Laboratory (NOL). The Jet Propulsion Laboratory of the California Institute of Technology, a contractor owned and operated facility involved in rocket research since

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[13] Percival Brundage, James R. Killian, Jr., and Nelson A. Rockefeller, "Memorandum for the President," Executive Office of the President: President's Advisory Committee on Government Organization (March 15, 1958). NASA Historical Documents Collection, NASA Headquarters, Washington, D.C. The political and legislative origins of the National Aeronautics and Space Administration are described in Walter A. McDougall, ...*The Heavens and The Earth: A Political History of the Space Age* (New York: Basic Books, 1985), Chapter 7, "The Birth of NASA," and Enid Curtis Bok Schoettle, "The Establishment of NASA," in Sanford A. Lakoff, ed., *Knowledge and Power. Essays on Science and Government* (New York, 1966).

1936, was also transferred from the U.S. Army to NASA. The Manned Spacecraft Center in Houston and the Kennedy Space Center at Cape Canaveral were added within the next two years.[14]

Predominating among NASA's initial cadre, the scientists and engineers of the NACA and the ABMA had staked their careers on institutions that conducted research in aeronautical and missile systems for both industrial and military clients. They also shared institutional cultures that placed a premium on in-house technical competence and a collegial research environment thought conducive to engineering innovation.

NASA's founding cadre may have valued in-house competence and performance above all else, but necessity, good politics, and the agency's first Eisenhower-era administrator (T. Keith Glennan) would conspire to transform the new organization into one which relied heavily on contracts with private industry to carry out its work.[15] The notion of relying on private industry (and universities) for goods, services, and research and development was not original with NASA; the practice had its roots deep in American history.

Since the beginning of the republic, Americans have shared a widespread mistrust of large government establishments. Coupled with this mistrust has been a public faith in

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[14] At the beginning of 1961, the old NACA laboratories and Marshall Space Flight Center accounted for 49% and 33%, respectively, of NASA's employees. Informally structured, the NACA had been overseen by its Main Committee and various technical subcommittees, its research conducted largely by civil servants located at Langley Aeronautical Laboratory in Hampton, Virginia (est. 1917), Ames Aeronautical Laboratory at Moffett Field, California (est. 1939), the Flight Research Center at nearby Muroc Dry Lake (est. 1946), Dryden Flight Research Center (after 1976), and the Lewis Flight Propulsion Laboratory in Cleveland, Ohio (est. 1940). The 157 personnel who had been working on the Navy's Project Vanguard, which became the nucleus of the Goddard Space Flight Center (est. 1959), were transferred to NASA in 1958 from one of the Navy's own in-house research laboratories, the Naval Research Laboratory. They were soon joined by 63 more who had been working for the Naval Research Laboratory's Space Sciences and Theoretical divisions. The next large group to transfer to NASA was the 5,367 civil servants from the U.S. Army's Ballistic Missile Agency (ABMA) at Redstone Arsenal, in Huntsville, Alabama. The ABMA had been essentially an in-house operation. The youngest NASA installations, the Manned Spacecraft Center (est. 1961 and renamed Johnson Space Center in 1973) and Kennedy Space Center (est. 1962), were initially staffed by personnel from Langley Research Center and the ABMA.

[15] T. Keith Glennan, *The First Years of NASA: Events and Impressions as Recalled by T. Keith Glennan, First Administrator of NASA*. 2 Vols. (Typescript and Privately Bound, 1964). NASA Historical Documents Collection, NASA Headquarters, Washington, DC.

private enterprise that, through the mechanism of a free market, was thought the best guarantor of economic growth and a free society. On this usually bi-partisan ideological foundation, and partly in reaction to the alleged excesses of the New Deal, Federal policy (implemented by the Bureau of the Budget--after 1970 the Office of Management and Budget) encouraged government agencies to acquire their goods and services from the private sector.

The military services had had the most experience with government procurement since they had been acquiring equipment and logistics support from the private contractors since the early 19th century. As a result of the U.S. Army's Manhattan Project and the ballistic missile programs managed by the U.S. Air Force's Research and Development Command,[16] both services came to rely on private contractors for advanced engineering and development work as well--the Air Force going so far as to create the Rand and Aerospace corporations. Within a year after NASA was established the General Services Administration authorized the agency's use of the Armed Service Procurement Regulations of 1947, which contained important exemptions, tailored for research and development work, from the principle of making awards to the "lowest responsible bidder."

"Contracting out" also had the virtue of necessity. Most of the experience in the country in related missile and high-performance aircraft development in 1958 centered in industry, which had worked as contractors to the military. Thus the resources of industry could be marshalled more effectively *by* the government than reproduced *within* the government. NASA would be able to mobilize the talent and institutional resources already in existence in the emerging aerospace industry and the country's leading research

[16] The U.S. Air Force was created out of the U.S. Army Air Forces under the Defense Reorganization Act of 1947 that established the Department of Defense.

universities.[17] Finally, reliance on contracts with private industry promised the political advantage of distributing Federal funds, which were reallocated through NASA's centers around the country, and as a consequence creating within the Congress a political constituency with a material interest in the health--and management--of the space program.

'Program Management'

Not only were NASA's procurement procedures based on those of the military establishment, but NASA made extensive use of the military's experience in program management as well. The ratio of military detailees working in NASA increased steadily between 1960 and 1968. Their importance to the Apollo program is suggested by the fact that the percentage of total military detailees represented by those at Marshall Space Flight Center and Johnson Space Center (where Apollo development work was principally managed) increased from 31 percent in 1961 to 75 percent in 1966.[18] Many of the detailees were Air Force or Navy career officers previously assigned to program or operations management positions. For example, 103 of the roughly 180 military detailees in NASA at the beginning of 1963 were career Navy or Air Force officers.[19]

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[17] One NASA installation, the Jet Propulsion Laboratory of the California Institute of Technology in Pasadena, California, would remain wholly a contractor operation. For an excellent and brief discussion of the NASA acquisition process, see Arnold S. Levine, *Managing NASA in the Apollo Era*, NASA SP-4102 (Washington, D.C.: 1982), Chapter 4. For background see Clarence H. Danhof, *Government Contracting and Technological Change* (Washington, D.C.: The Brookings Institution, 1968) and Merton J. Peck and Frederick M. Scherer, *The Weapons Acquisitions Process: An Economic Analysis* (Boston: Harvard University Press, 1962).

[18] Jane Van Nimmin and Leonard C. Bruno with Robert L. Rosholt, *NASA Historical Data Book, Vol. I: NASA Resources 1958-1968*. NASA SP-4012 (Washington, D.C.: National Aeronautics and Space Administration, 1988), pp. 80-81, 98-99.

[19] Memorandum from Albert F. Siepert to James E. Webb, February 8, 1963. NASA Historical Documents Collection, NASA Headquarters. A list of positions "requiring USAF officers" forwarded by NASA to the Department of the Air Force in 1964 included: director, program control, Apollo; director, program control, Saturn V; deputy director for program management, Apollo spacecraft; assistant to director for program management, Saturn V; chief, configuration management, Apollo spacecraft; configuration management officer, Saturn V; chief, configuration management, Saturn I-IB;
(continued...)

So impressive was the management undertaking involved in fabricating the Apollo/Saturn systems that even before the historic Apollo 11 mission left the launch pad on the morning of July 16, 1969, the Committee on Science and Astronautics of the U.S. House of Representatives convened key industry Apollo/Saturn contractors and NASA program managers for a review of their program management practices. Their published testimony makes tedious reading, littered as it is with charts and acronyms and general ineloquence; but it has an important story to tell.

Unlike the industrial firms of earlier periods of American history, the firms that supplied the aerospace programs of NASA and the military were engaged in the low-volume production of items that were complex, novel, and relatively unique. The novelty and relative uniqueness of the aerospace industry's products necessarily meant that little could be standardized. Thousands of 'end items' produced by dozens of different suppliers and manufacturers had to be produced on schedule and fit and function together at levels of reliability required for 'manned' missions. Thus the efficiency-seeking attributes of the traditional 'American system of manufacture' (use of standardized interchangeable parts and continuous process manufacture) no longer applied.

The 'efficiency' inspired organizational structure of functionally distinguished units (e.g., finance, accounting, marketing, research, facilities, engineering, testing, manufacture, logistics, etc.), adequate for the production of essentially undifferentiated products, would not suffice. "Early in the development phase of the Apollo/Saturn effort," recalled Rocketdyne's vice-president of management planning and controls, "Rocketdyne management recognized that the traditional functional organizational alignment was not adequate to direct the effort of the various engine programs effectively. To ensure the

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[19](...continued)
configuration management officer, Gemini; configuration management officer, Apollo launch site; assistant deputy director for program management, Apollo program office; configuration management officer; and chief, mission requirements, Apollo. Attachment to Memorandum from Eugene M. Zuckert, Secretary of the Air Force, to Hugh L. Dryden, Deputy Administrator of NASA, May 27, 1964. NASA Historical Documents Collection, NASA Headquarters.

necessary concentration of effort, it was decided to establish separate product organizations with responsibility for the development of specific types of engines."[20]

Not all companies had been organized like Rocketdyne; Boeing's management had already become "basically decentralized and organized around product line responsibilities," but one in which "the functional executive provides a unifying force which crosses the boundaries of the various line organizations...." At Boeing, the "line organization managers" acquired the "ultimate authority and responsibility for carrying out The Boeing Co.'s contractual and related commitments to its customers."[21]

The ability to respond intelligently and quickly to failures would become a critical management responsibility. That responsibility was felt especially acutely among government (NASA) managers responsible for the Saturn program's success:

> ...such [Apollo/Saturn program management] features as actions for early problem detection, actions and process for problem solving, and action and processes for recovery from anomalies and failures are basic features...[22]
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> ...the system must provide visibility and flexibility. You need the visibility to identify nonproductive tasks and you need the flexibility to redirect the effort. Otherwise, you would be using up limited resources on tasks that were no good. Visibility and flexibility imply a knowledgeable decision point close to the work.[23]

The project manager, the program manager, and their staffs: they became the "knowledgeable decision" points "close to the work" that government and industry created to manage the development and production of specialized technological systems.

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[20] "Apollo Program Management: Staff Study for the Subcommittee on NASA Oversight, Committee on Science and Astronautics, U.S. House of Representatives, 91st Congress, 1st Session (July 1969), p. 122.

[21] H. H. Gunning, (Boeing Co.) Ibid., pp. 15-16.

[22] Eberhard F.M. Rees (NASA Marshall Space Flight Center), *Ibid.*, p. 9.

[23] R. L. Brown (NASA Marshall Space Flight Center), *Ibid.*, p. 13.

"The heart of the Program Management System," explained one NASA program manager,

> is the Project Manager who is responsible for the design, fabrication, test, delivery, and successful performance of a major piece of hardware, a product best exemplified by a stage of the launch vehicle. To achieve his goal, the Project Manager has clear lines of authority and responsibility as well as clear channels of coordination with supporting entities. These have been committed to clear, concise documented agreements.... In addition to management by product, such as the S-II Stage, the Program and Project managers also manage, to an extent, by function. These functional management elements...permeate the entire program.... These elements insure, within their disciplines, a continuous coordination between the functional elements [among other NASA organizations]...enabling many things to be handled at the working level....[24]

Critical communication and coordination between government 'customers' and industrial contractor organizations required of the latter that they develop management systems that paralleled those NASA established. One Rocketdyne manager described NASA's (and DoD's) impact on the aerospace industry this way:

> During the past 7 years NASA has had a significant and favorable influence in the development of advanced management systems within Rocketdyne. Program Planning and control requirements specified by both DoD and NASA have stimulated such management systems activity as development and implementation of the Rocketdyne Cost Management System, the Mechanized Production control System, the Mechanized Inventory control System coupled with the Required Inventory Control System, the Mechanized Quality Performance System, and the Mechanized Time-keeping System, to name a few. New concepts such as the well-defined program organization operating in a program/functional matrix

[24] Edmund F. O'Connor, "General Program Management," *Ibid.*, p. 247-48.

relationship, the assignment of specific individuals to manage all activity on product-oriented elements of program work breakdown structures, and the application of the multiple accountability technique also saw their genesis during this period.[25]

McDonnell Douglas attributed its success in designing and developing the Saturn S-IV upper stage of the Saturn I launch vehicle to its realization that "the Saturn/Apollo system, the greatest engineering task in history,

> required a much more intimate integration of Government and industry resources than had previously been the case.... Management techniques geared to the production of aircraft in volume had to be slanted toward the complexity and state-of-the-art nature of the Saturn program. MDAC-WD [McDonnell Douglas Astronautic Co.-Western Division]...established clear, detailed requirements, and provided for precise command and control through total program visibility... The MDAC-WD found it necessary to realine [sic] its organizational structure and management techniques to accommodate the unique requirements of this great, joint, government-industry venture.

MDAC-WD emphasized two management principles: "(1) provide autonomy and freedom to company personnel to interface directly with the customer's [government] managers, and (2) provide top management with the means to evaluate program status and support the program manager's needs for resources. (This was made possible by the projectized program organization placed in a matrixed division framework.)"

McDonnell Douglas had to develop ways to respond efficiently to "the requirements of precise configuration control, exacting quality standards, extensive contract change traffic, and even fundamental revision in the type of contract" under which the corporation worked. Most of all they had to be certain that there would be "no

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[25] *Ibid.*, p. 126.

failures in flight," a certainty they hoped to achieve through high reliability and quality controls. Reliability and quality were in constant jeopardy from configuration changes:

> The overriding objective was to avoid flight failures.... Rigorous management of configuration changes avoided a near chaotic condition which would have resulted from the inclusion of results from various test analyses in the hardware.... It was considered a law that anything that flew on [AS-] 205[26] had to be flown on [the preceding AS] 204, and anything on [AS-] 503 had to be on [AS-] 502....
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> To avoid mission failures, management went into a very comprehensive, in-depth, system, subsystem, and component development. The object was early exposure of weaknesses through repetitive forced exposures. The underlying and most fundamental activities are the ground test program, development tests, qualification tests, formal qualification tests, repeat qualification tests, and reliability verification tests, which are essentially component and subsystem oriented.

Confidence could not, however, be built around an edifice of bureaucratic procedures and concurrence levels that would tend to guarantee only that nothing got accomplished. Decisions had to be made promptly, and with reliable, instant access to all necessary information:

> The program director has all of his decisionmakers immediately available--often in one room--and they have an opportunity to look at every important piece of work to be authorized, including details that many would consider completely unnecessary.... Superimposed upon the formal systems are the informal systems of communication through face-to-face contact. These are judged to be equally key

[26] 'AS' refers to suborbital and earth- and lunar-orbital Apollo-Saturn vehicles in the Apollo flight program. These were differentiated by the number sequence following 'AS.' See Appendix C, "Apollo Flight Program," in Courtney G. Brooks, James M. Grimwood, and Loyd S. Swenson, Jr., *Chariots for Apollo: A History of Manned Lunar Spacecraft*. NASA SP-4205. (Washington, D.C.: U.S. Government Printing Office, 1979), pp. 381-393.

> to the success of the program. The management of the Saturn Program at MDAC-WD has not attempted to sit in an office examining status reports to reach significant management decisions...program management's visibility is substantially improved by daily personal contacts between company and customer [NASA] personnel, and decisions are guided by information and facts which thus come to light.

The importance of full communication--not only of factual information, but of hesitancies, insights, poorly articulated concerns--received repeated emphasis in McDonnell Douglas's review of its own maturation during the Apollo-Saturn program:

> On a program the size of Saturn/Apollo, the problem of communicating effectively impinges on all transactions, from the simplest, vis-a-vis contact, to major program negotiations. Throughout the program, at all levels, heavy emphasis was laid on the personal encounter.

Looking back, reflected a McDonnell-Douglas witness, "managing Saturn has been almost as complicated and demanding a task as overcoming attendant technical difficulties.

> While geared to take on the management of this immense and complex program by valuable experience gained with Thor, Nike, and other families of missiles and space systems, no previous program compared with Saturn for scope, size and complexity.... significant strides were made in learning how to control a major program of the size and magnitude of the Saturn project.[27]

[27] In May 1960, when it received the Saturn IV contract, the Mcdonnell Douglas Astronautic Co., Western Division (MDAC-WD), was known as the Douglas Aircraft Co. MCDAC-WD was awarded in 1962 a second NASA contract to design and develop the Saturn S-IVB, the uppermost stage of the two other members of the Saturn launch vehicle family, the Saturn IB and Saturn V. Excerpts are from McDonnell Douglas Testimony, "Apollo Program Management: Staff Study for the Subcommittee on NASA Oversight," Committee on Science and Astronautics, U.S. House of Representatives, 91st Congress, 1st Session (July 1969), pp. 61-74.

Demobilization

The Apollo Program was unarguably an enormous achievement. Nevertheless the transient motives behind the program, and the rapid mobilization of funds and personnel that made success possible, impeded the gradual evolution of a stable and broad public consensus about the nation's purpose in space. As more than 30,000 NASA engineers worked at their daily routines during the mid-1960's, pursuing the adventure to which President Kennedy had summoned them, the solid ground of common national purpose had already begun to shift ominously under their feet. American violence at home, as race-related riots spread from urban ghetto to urban ghetto, was matched by American violence in Viet Nam. By 1965, John F. Kennedy lay buried, and 3 years later he would be joined by Robert Kennedy; they, and Martin Luther King, would also be victims of violence. Raising the specter of runaway inflation as costs for the war in Vietnam and the social programs of the "Great Society" mounted, Lyndon Johnson's economic advisers persuaded the President in 1965 that the budget for the space program would have to be contained. For an ambitious space program to follow the Apollo adventure, there was diminishing enthusiasm outside NASA. In fiscal year 1966, NASA's budget began its downward slide (though actual expenditures for 1966 were the highest of the decade).[28]

The political consensus that had produced the visionary National Aeronautics and Space Act of 1958 and the single-purpose Moon landing program--with its important consequences for American industry--began to dissipate before the last Apollo mission was flown.[29] NASA's fiscal year 1971 budget took a battering from the OMB in 1969, forcing Webb's successor Thomas O. Paine (1969-70) to complain that the OMB had ignored the

[28] Robert A. Divine, "Lyndon B. Johnson and the Politics of Space," in Robert A. Divine, ed., *The Johnson Years: Vietnam, the Environment, and Science*, Vol. II (University Press of Kansas, 1987), pp.217-253.

[29] The last Apollo mission was the Apollo-Soyuz Test Project jointly conducted with the Soviet Union. An especially adapted Apollo command and service module joined with a Soyuz spacecraft in July 1975 and spent two days docked together in orbit while American astronauts and Soviet cosmonauts ate and visited together and performed joint scientific investigations.

ignored the recommendations of the White House's own Space Task Group, chaired by Vice-President Spiro T. Agnew. A staunch supporter of a vigorous 'manned' space program (and hence further Apollo 'manned' expeditions to the Moon), Paine was willing to risk continued production of the Saturn launch vehicle and the Viking project (to launch an 'unmanned' spacecraft to land on Mars) in order to pay for further 'manned' lunar missions. Viking survived, as did a proto-space station (Skylab) fashioned from Apollo-Saturn hardware and flown during 1973; but the mighty Saturn did not. Instead, NASA was able to persuade the Nixon administration that a new Space Transportation System featuring a reusable orbiter spacecraft and rocket boosters would be an economical alternative to the use of large 'throw away' launchers like the Saturn.

The organization that built America's civil space program in the high-noon of the Cold War groped about for a marketable mission. In 1971 Deputy Administrator George M. Low even contemplated recasting NASA as a national technology agency, responsible not only for aeronautics and space research and development, but for a wide range of "technological solutions" for national problems such as alternative power and energy sources, environmental pollution, improved transportation systems, health care systems, productivity of services, education, and housing.[30] That others were thinking in this vein as well is apparent from the non-aerospace responsibilities added to NASA's authorizing legislation during the 1970s.

The fortunes of the 'Space Act' reflect the diminished national priority of a great national adventure in space as successive amendments stripped the statute of its originally well-focused declaration of purpose. In 1964, NASA's 10 top executives lost their special pay status; by 1978 NASA lost all statutory authority to establish scientific or professional positions outside of the federal government's 'general schedule' of civil service positions.

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[30] Memorandum from George M. Low to the NASA Administrator [James C. Fletcher], Subject: NASA as a Technology Agency (May 25, 1971), NASA Historical Documents Collection, NASA Headquarters.

In 1973, the National Aeronautics and Space Council, which could have served as a vehicle by which the executive branch crafted an interagency consensus around a well-defined program, was abolished. From 1974 onward the Space Act also became burdened with numerous charges to the agency occasionally having only the most tangential relation to the agency's original purpose. In 1974 NASA was directed to develop and demonstrate "solar heating and cooling technologies," in 1975, to monitor and investigate the "chemical and physical integrity of the Earth's upper atmosphere," in 1976, to develop "more energy efficient and petroleum conserving and environment preserving ground propulsion systems," in 1976, to develop and demonstrate "electric and hybrid [ground] vehicle" technologies; and in 1978, to develop advanced automobile propulsion systems *and* to assist "in bioengineering research, development, and demonstration programs designed to alleviate and minimize the effects of disability."[31]

Notwithstanding the continuing aspirations of space scientists and space travel enthusiasts both within and without NASA, the Congress was demoting the national urgency of the 'Space Race'. Because this ostensibly peaceable campaign of the Cold War was fought openly, and through the means of a civilian agency, there was no occasion or felt need to declare peace and provide for an orderly demobilization. But demobilize

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**NASA and NASA Contractor Personnel: Selected Years, 1965 - 1989**[32]

| | **1965** | **1967** | **1968** | **1980** |
|---|---|---|---|---|
| Civil Service: | 34,049 | 35,860 | 34,641 | 23,470 |
| Contractor (Est.): | 411,000 | 309,100 | 246,200 | 20,700 |

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[31] *National Aeronautics and Space Act of 1958, As Amended*. Printed for the Use of the National Aeronautics and Space Administration (January 1990).

[32] Sources: *NASA Historical Data Book*, Vol. 1, p. 118; *NASA Pocket Statistics*, National Aeronautics and Space Administration (January 1990), pp. C-24, C-25, C-27.

NASA did[33]; it had to, as did its contractors. Between 1965 and 1968 over 150,000 NASA-supported jobs evaporated; during the 1970s an additional 236,671 persons once employed by NASA or its contractors had to find other jobs. Some of those jobs were undoubtedly absorbed by the Department of Defense, where civilian employment increased by 160,000 between 1965 and 1970. But after the end of U.S. military involvement in Viet Nam in 1973, most of those positions were lost as well.[34]

One aerospace engineer at NASA's Kennedy Space Center at Cape Canaveral, Florida remembers the winter of 1970-1971 this way:

> In December of 1970, at the end of the Apollo program...this area was becoming a very, very tough area in which to find a job because of all the layoffs..... Contractors...couldn't give a house away here.... [When Kennedy Space Center closed down Apollo program operations] the contractor [Singer-Link] literally just walked away and left everything -- just walked out of there on a Friday like they were coming back on the Monday. All of the logistics and space parts, everything, was just left.... The people just walked out and at the work benches the little soldering irons were still plugged in. There was still food in the refrigerator.... There were literally thousands and thousands of dollars of useable parts.... We had all been so hyped on this thing of going to the Moon. And then, to all of a sudden wake up one day with the realization of 'there's no more'.... There was no diversification for these guys that had just finished launching the Apollo launch vehicle, which was probably one of the greatest engineering marvels of its time. They would [end] up on the streets, out of work, with no place to go. I knew a

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[33] As measured by NASA appropriations, which haven't recovered their 1965 level in constant dollars. See also "Towards A New Era in Space: Realigning Policies to New Realities," Committee on Space Policy, National Academy of Sciences and National Academy of Engineering (National Academy Press: Washington, D.C., 1988).

[34] By 1975 civilian employment at the Department of Defense declined to 1,041,829 from its 1970 high of 1,193,784 -- or slightly over its 1965 level of 1,033,775. "Paid Civilian Employment in the Federal Government, by Agency, All Areas, 1965 to 1979," *Statistical Abstract of the United States* (Washington, D.C.: U.S. Government Printing Office, 1979), p. 277.

couple of engineers that [sic] were actually at the gas station pumping gas.... One of the engineers...got into real estate and has left the area. He said, 'I wouldn't go back for all the tea in China. Just because of the heartbreak.'[35]

The number of government employees NASA was able to support continued its steady decline to about two-thirds (in 1988) of the almost 36,000 people on the NASA payroll in 1966.[36]

George M. Low and his successor, James C. Fletcher,[37] bowing to budget pressures dominating Washington's political climate, seized upon a strategy opposite to that which had guided NASA and its contractor managers in the Apollo era. In 1971 they persuaded the Nixon White House that the proposed Shuttle program[38] would "take the astronomical costs out of astronautics."[39] Low correctly attributed that "high cost" of "doing business in space" to the "great sophistication" with which most space systems are designed in order to "operate acceptably with low allowable weight" and to the fact that "most systems are individually tailored for their mission, used once or twice, and then never used again. Thus the economies of producing a number of like systems are never attained."

An economics research firm contracted by NASA reported in 1971--on the basis of figures and formulas that had to have been somewhat speculative--that such a system

[35] Quoted in Sylvia Doughty Fries, *NASA Engineers and The Age of Apollo*. NASA SP-4104 (Washington, D.C.: U.S. Government Printing Office, In Press.).

[36] NASA contractor employees outnumbered civil servants 3 to 1 in the early 1960's, ballooned to 10 to 1 in 1966, and subsided to about 2 to 1 in the 1980's. Jane Van Nimmen and Leonard C. Bruno with Robert L. Rosholt, *NASA Historical Data Book: NASA Resources, 1958-1968*, Vol. I, SP-4012 (Washington, DC: National Aeronautics and Space Administration, 1988), p. 118 and *NASA Pocket Statistics* (Washington, D.C.: National Aeronautics and Space Administration, 1986), p. C-27. Numbers of contractor employees can only be estimated.

[37] Low served as Acting Administrator upon Paine's resignation in September, 1970 until Fletcher was sworn in as NASA Administrator April 27, 1971.

[38] Properly referred to as the 'Space Transportation System', i.e., the Shuttle Orbiter, External Tank (non recoverable) and twin Solid Rocket Boosters.

[39] Statement by the President, the White House, January 5, 1972 (NASA Historical Documents Collection, NASA Headquarters).

would be economical *assuming* a flight rate of "between 300 and 360 Shuttle flights in the 1979-1990 period, or about 25 to 30 Space Shuttle flights per year."[40] Even more portentous was what the assumed flight rate, in turn, implied: NASA--its organizational strength rooted in its history as an advanced technology research and development organization--would be just as successful at operating a sophisticated, but routine, transportation system.

Low recognized that the agency and its contractors would have to change to operate a cost-effective space transportation system, though whether he grasped just how fundamental a change was involved is not clear. NASA would now, asserted Low, have to abandon the strategy of developing "individually tailored technologies" and, instead, "focus on *multiple-use, standardized* systems" (emphasis author's).[41] In 1983, the Shuttle's series of flight tests completed, the Congress added to the statutory 'activities' in which NASA was authorized to engage "the *operation of a space transportation system...*" (Sec. 103; (1)(C); emphasis author's).

While Low may not have thought of it in these terms, he was, in effect, asking the NASA organization and its industrial partners to turn back the clock to a time when American manufacturers strove for the efficiencies of standardized, volume production to exploit an expanding market. It was a bold risk that he was taking. To the extent that the nation's civil space program now hinged on the success of the Shuttle program, NASA would have to undertake the most profound reversal in its managerial habits that any organization could be asked to make. The agency and contractors would have to unlearn the strategies they had developed in order to design and produce the complex, one-of-a-kind, and reliable aerospace systems that carried men to the Moon. Would they succeed? Would NASA's inherited research culture, better suited for a research and development

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[40] Mathematica, Inc. *Economic Analysis of the Space Shuttle System*, National Aeronautics and Space Administration Contract NASW-2081 (January 1972).

[41] Memorandum from Deputy Administrator George M. Low to NASA program office administrators, May 16, 1972. NASA Historical Documents Collection, NASA Headquarters.

mission, be able to respond to the administrative and logistical demands of routine and efficient operations?

A partial answer came in the form of the report issued by the Presidential Commission on the Space Shuttle Challenger Accident that had occurred January 28, 1986. Chaired by former Secretary of State William P. Rogers, the commission concluded that the fiery end of Mission 51-L was caused by "the failure of the pressure seal in the aft field joint of the right Solid Rocket Motor. The failure was due to a faulty design unacceptably sensitive to a number of factors. These factors were the effects of temperature, physical dimensions, the character of materials, the effects of reusability, processing, and the reaction of the joint to dynamic loading."[42]

The commission was also impressed by proximate causes of the accident to which it ultimately gave great weight: A top-level decision to launch that had been inadequately informed about the sensitivity of the O-rings on the Solid Rocket Boosters' aft field joints to the inordinately cold temperatures prevailing at the time of the launch, a "silent" safety, reliability, and quality assurance program, *and* an organizational failure to adapt to the requirements of a truly operational transportation system. These included lack of schedule discipline and inadequate logistics to support the flight rate that would enable the agency to deliver the economies promised when President Ronald Reagan announced in 1982 that "the first priority of the STS program is to make the system fully operational and cost-effective in providing routine access to space."[43]

During the next two and a half years NASA redesigned known flaws in the Shuttle's systems, elevated the safety, reliability, and quality assurance organization, and tightened decision-making channels between its centers and headquarters. The result was a successful 'return to flight' in September 1988. Wags remarked that the flight of STS-26

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[42] *Report of the presidential [Rogers] Commission on the Space Shuttle Challenger Accident* (Washington, D.C.: U.S. Superintendent of Documents, June 6, 1986), p. 72.

[43] Quoted in *Report of the Presidential Commission on the Space Shuttle Challenger Accident*, p. 164.

a successful 'return to flight' in September 1988. Wags remarked that the flight of STS-26 was probably the safest Shuttle mission imaginable. Underlying management issues--especially whether NASA could, or even should, attempt to transform itself into an operations organization--proved more stubborn.

In 1988 NASA did establish an associate administrator level Office of Space Operations, responsible for the space tracking network, data systems, and the Kennedy Space Center. But the competing demands of operations and research and development continued to trouble the agency whenever (as in 1990 and early 1991) its heightened safety procedures detected problems with Shuttle hardware requiring protracted 'stand downs' of one or more Shuttle spacecraft. The National Academy of Public Administration (NAPA), in a 1988 study led by former Apollo program director and Air Force General Samuel C. Phillips, argued:

> the term 'operational' as applied to commercial aircraft, to ships, or to mass-produced articles of defense will most likely never apply to space systems in that same context. What we do see, however, are large, complex space systems such as the Shuttle and the [future] Space Station that are or will be largely driven by operational issues--turnaround time between flights, manifesting, retrofitting of design changes for safety, cost or payload capability purposes, logistics, training of basic and science crew members, and so on. These are *not* the basic work of research and development leading to new concepts and ideas for future space systems, nor for expanding knowledge of the universe and discerning the implications of that knowledge for life on this planet or elsewhere.[44]

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[44] National Academy of Public Administration. Samuel C. Phillips, Chairman. *Effectiveness of NASA Headquarters: A Report for the National Aeronautics and Space Administration*. February 1988. Quoted in *Report of the Advisory Committee on the Future of the U.S. Space Program* (Washington, D.C.: U.S. Government Printing Office, December 1990), p.38.

Contested Roles

Underscoring the uncertainty of NASA's role within the constellation of federal programs, President George H. Bush reconstituted in February 1989 an interagency policy council for the nation's space activities when he established the National Space Council, chaired by Vice President Dan Quayle. The Advisory Committee on the Future of the U.S. Space Program, established under the auspices of the Council, concluded that NASA's primary business should return to what it had been in the 1960's--the scientific exploration of space and aerospace research and development. Urging that "perfection" become the single most important aim for NASA's organizational culture, the "Augustine Committee" reasserted the managerial outlook of the Apollo era:

> ...perfection can most closely be approached in an organization whose ethos is one of excellence and where this ethos permeates everything it does.... It must be clear to all that, in this culture, *excellence is more important than schedule and more important than cost--even though these too are important*--and that management at all levels can be reliably counted upon to act with this as its set of values (emphasis author's).[45]

At the same time, the committee recognized that so long as NASA was responsible for the Shuttle, the agency would have to adapt to the demands of a successful operating organization. The comments of many who spoke with the committee "frequently referred to the consuming effect this [flight operations] responsibility can have on NASA's senior management, limiting the time available for the planning and direction of leading-edge technological developments." Committee witnesses also expressed the belief that "the merging of operations into a largely developmental organization does not foster the building of a professional operations cadre which can best manage this vital responsibility."

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[45] *Report of the Advisory Committee on the Future of the U.S. Space Program*, p.16. The committee was informally named for its chairman, Norman R. Augustine, Chairman and CEO of the Martin Marietta Corporation.

The Augustine committee tried to resolve the conflicting roles in which it had cast NASA by urging the agency to effect "an organizational separation, from the top of the agency down, on the two matters of space flight operations and space system development." NASA, urged the committee, should strive for

> safe operation [of the Shuttle], performed as efficiently and routinely as its complexity permits, and not burdened by excessive layers of management that are the legacy of the development era and recovery from the Challenger accident.[46]

And so, a compromise was struck. NASA should retain its identity and role as a research and development organization, the identity with which most of its people were comfortable and upon which its self-esteem depended, and it would not have to lose its most visible post-Apollo achievement--the Shuttle--to do so. Suggestions that Space Shuttle operations be transferred to some other, and perhaps especially created, government entity, or to the private sector, had been rejected. This meant that a significant portion of the organization would have to learn how to operate a transportation system. Like most compromises, however, this answer to the question of NASA's place in the nation's agenda and economy was equivocal at best. Whether the Congress, or NASA's internal budgetary politics, would yield the wherewithal for the agency to pursue this dual role effectively remained to be seen.

Less equivocal was the Augustine committee's answer to the question of whether NASA should continue to enjoy a monopoly as the country's sole provider of access to space. The answer was no. This resolution of the issue restored a more ideologically comfortable equilibrium between government and private sector roles in the country's industry and commerce -- this time on the yet to be fully exploited frontier of space. Earlier, the Republican administration of Ronald Reagan had announced in 1984 a National Commercial Space Policy to encourage private enterprise in space, and the Congress followed suit with an amendment to the 1958 Space Act directing NASA to

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[46] *Report of the Advisory Committee...*, p. 40.

"seek and encourage to the maximum extent possible the fullest commercial use of space." In the last year of his second administration, Reagan directed *all* "Federal agencies" to "procure existing and future required expendable launch services directly from the private sector to the fullest extent feasible" and the Congress once again endorsed the shifting balance with an amendment to the Space Act.[47]

Furthermore, the Augustine Committee called for a restoration of the traditional role of the private sector as designer, developer, and producer when it recommended that "an appropriate balance [be achieved] between in-house and external activity." In the more than three decades that had passed since NASA was created, the committee pointed out, there had developed a solid basis of space technology skills in both industry and academia. The committee was saying implicitly that one of NASA's purposes--a purpose it had now served--was to develop and transfer to the private sector "know-how" that the private sector could or would not have developed itself. No longer was it necessary, continued the Augustine committee, for NASA to match every development being contracted with comparable in-house laboratory skills. (Not mentioned was the principal reason NASA had struggled to maintain in-house technical strength in the first place: to be meaningfully accountable for the performance of its industrial contractors.) Citing the counter example of national security aerospace R&D procurement, the committee argued that NASA could 'buy smart' with fewer civil service project and program personnel. "NASA should concentrate its 'hands-on' expertise," the committee recommended,

> in those areas unique to its mission, and avoid the excessive diversion of technical or mission specialists to functions which could be performed elsewhere. Contract monitoring is best accomplished by a cadre of professional systems managers with

[47] "Fact Sheet: The President's Space Policy and Commercial Space Initiative To Begin the Next Century," The White House, Office of the Press Secretary (February 11, 1988); *National Aeronautics and Space Act of 1958, As Amended*. Printed for the Use of the National Aeronautics and Space Administration (January 1990).

appropriate experience. Increased use of performance requirements, rather than design specifications, will further increase the effectiveness of this approach.

Only tell industry what you want, the committee seemed to say; let the aerospace industry decide how to provide it. With these uninspiring words some of the most accomplished and authoritative voices of the U.S. aerospace community pronounced an era at an end.[48]

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The rapid mobilization of government and the aerospace industry to carry out the Apollo program led to a disequilibrium in the respective roles of public and private enterprise in the American peacetime economy. Previous government mobilizations had occurred only during wartime, were understood to be temporary, and were followed by a planned and orderly demobilization. Government intrusion into the management practices of firms was minimal, manipulation of prices and supply being a more politically palatable means of assuring output of the necessary materials and equipment.

The Apollo mobilization was different not only because it was a civilian and peacetime mobilization. It was different because government affected private sector management internally--not by force or decree, but by necessity. Government and industry managers alike learned the importance of person-to-person communication when the perfection and reliability of complex technologies involving over hundreds of producers

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[48] *Report of the Advisory Committee....*, pp. 41-42. The Augustine Committee consisted of: Chairman Norman R. Augustine, Chairman and CEO of the Martin Marietta Corporation, also formerly Under Secretary of the Army; Laurel L. Wilkening, Provost and Vice President for Academic Affairs of the University of Washington, also formerly Vice Chairman of the National Commission on Space (1985); Edward C. Aldridge, Jr., President of the Aerospace Corporation, also formerly Secretary of the Air Force; Joseph P. Allen, President of Space Industries, Inc., also formerly NASA Astronaut; D. James Baker, President of Joint Oceanographic Institutions, Inc., also member of the National Research Council Committee on Global Change and the Ocean Studies Board; Edward P. Boland, Member of the U.S. House of Representatives, 1953-1988; Daniel J. Fink, President of D. J. Fink Associates, Inc., also formerly Vice-President of the General Electric Company and Deputy Director, Strategic & Space Systems of the Department of Defense; Don Fuqua, President and General Manager of the Aerospace Industries Association, also formerly Member of the U.S. House of Representatives, 1963-1987; Robert T. Herres, President of Property and Casualty Insurance Division at USAA, also formerly Vice Chairman of the Joint Chiefs of Staff, Commander-in-Chief U.S. Space Command, and Commander of the Air Force Space Command; David T. Kearns, Deputy Secretary of the U.S. Department of Education, also formerly Chairman of the Xerox Corporation; Louis J. Lanzerotti, Distinguished Member of the Technical Staff, AT&T Bell Laboratories, and Chairman of the National Research Council Space Studies Board; and Thomas O. Paine, Chairman of Thomas Paine Associates, also formerly NASA Administrator (1968-1970).

were at stake. Private sector management structures and strategies had to change to adapt to the requirements of the unique products sought by the aerospace industry's principal customer. As a result, the 'American system', with its volume production and marketing of standardized products with interchangeable components and corresponding functionally distinguished management structures, had to be abandoned.

In its place NASA and its industrial contractors developed management strategies to produce highly sophisticated, one-of-a-kind products designed to operate reliably as components of complex, large-scale technological systems. The demands of quality and reliability were in constant tension with the novelty of these systems. "Program management," originating in World War II military weapons programs, became the standard management discipline throughout NASA and the aerospace industry. In this case, as in every previous case in the rise of big business in America, the nature of the marketplace and the nature of the product determined industry's management structure and principles.

Post-Apollo demobilization at NASA and among its contractors signalled a return to an earlier equilibrium amid a changing market for space activity. The American future in space was to be a future for commercial exploitation, not government enterprise. Government might continue to subsidize science (as it had since World War II) which was largely performed by universities and their contractors in any event. And government might continue to carry out the advanced research and development that private industry was unable or unwilling to support. But the business of transporting payloads into space should be given over to the private sector--with the exception of the Space Shuttle which NASA had been allowed to keep but is, in fact, operated by contractors to NASA. Within the public sector standardization, reusability, reliable and routine Shuttle operations as well as "off the shelf technology" were to be the watchwords for the civil space program. NASA had served the purpose for which it had been created at the height of the Cold War and might henceforth be seen more as a public service agency than the peaceful army that conquered the route to the Moon. In the process it has grown an industry and, together with that industry, shown that public and private enterprises can, together, achieve daring, massive, and complex technological triumphs.

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